

What is claimed is:

1. A copolymer comprising at least one first monomeric unit and at least one second monomeric unit, wherein the at least one first monomeric unit has a Formula I shown in Figure 1, and the at least one second monomeric unit is selected from (i) aromatic groups having Formula II shown in Figure 2, (ii) 6-membered-ring heteroaromatic groups having Formula III, shown in Figure 6; (iii) 5-membered-ring heteroaromatic groups having Formula IV, shown in Figure 7; (iv) aromatic groups having Formula V, shown in Figure 8, (v) fused ring aromatic groups having Formula VI, shown in Figure 9, Formula VII, shown in Figure 10, and Formula VIII through Formula XI, shown in Figure 11, and (vi) combinations thereof, where:

in each of Formulae I, II, III, IV, V, VI, VII, VIII through XI:

- R is a substituent on a carbon atom which can be the same or different at each occurrence and is selected from hydrogen, alkyl, aryl, heteroalkyl, heteroaryl, F, -CN, -OR¹, -CO₂R¹, -C_ψH_θF_λ, -OC_ψH_θF_λ, -SR¹, -N(R¹)₂, -P(R¹)₂, -SOR¹, -SO₂R¹, -NO₂, and beta-dicarbonyls having Formula XII shown in Figure 12 and as further described below under "Formula XII"; or adjacent R groups together can form a 5- or 6-membered cycloalkyl, aryl, or heteroaryl ring, such that:
- R¹ is a substituent on a heteroatom which can be the same or different at each occurrence and is selected from alkyl, aryl, heteroalkyl and heteroaryl; and
- ψ is an integer between 1 and 20, and θ and λ are integers satisfying Equation A1 below:

$$\theta + \lambda = 2\psi + 1; \quad (\text{Equation A1});$$

in each of Formulae II, III, IV, V, VI, VII, VIII, and IX:

- E can be the same or different at each occurrence and is a single bond or a linking group selected from arylene and heteroarylene;

in Formula IV:

A is independently at each occurrence C or N and γ is 0 or an integer selected from 1 or 2, such that when both A are N, then γ is 0; or when one of A is N and one of A is C, then γ is 1; or
5 when both A are C, then γ is 2;

Q is O, S, SO₂, or NR¹ where:

R¹ is a substituent on a heteroatom which can be the same or different at each occurrence and is selected from alkyl, aryl, heteroalkyl and heteroaryl;

10 in Formula V:

Q¹ is a carbonyl group, O, S, SO₂, or NR¹ where:

R¹ is a substituent on a heteroatom which can be the same or different at each occurrence and is selected from alkyl, aryl, heteroalkyl and heteroaryl;

15 W is H, alkyl or heteroalkyl; or both of W together can represent one single bond;

in Formula VI:

the two E's are in the 1,4-, 1,5-, 1,8-, 2,3-, or 2,6- positions;

in Formula VII:

20 the two E's are in the 1,4-, 1,5-, 1,8-, 2,3-, 2,6-, or 9,10- positions;

in Formula VIII:

a first E is in the 1, 2, or 3 position, a second E is in the 6, 7, or 8 position;

in Formula IX:

25 a first E is in the 2, 3, or 4 position; a second E is in the 7, 8, or 9 position; and

in Formula XII:

R² is selected from hydrogen, alkyl, aryl, heteroalkyl and heteroaryl;

30 δ is 0 or an integer from 1 to 12.

2. The copolymer of Claim 1, wherein R groups in one or more of the at least one first monomeric unit are independently selected from alkyl groups having 1 to 30 carbon atoms; heteroalkyl groups having 1-30
35 carbon atoms and one or more heteroatoms of S, N, or O; aryl groups having from 6 to 20 carbon atoms, and heteroaryl groups having from 2 to 20 carbon atoms and one or more heteroatoms of S, N, or O.

3. The copolymer of Claim 1 that excludes any vinylene monomeric units.

5 4. The copolymer of Claim 1 wherein each R group in each of Formula I, Formula II, Formula III, Formula IV, Formula V, Formula VI, Formula VII, Formula VIII, Formula IX, Formula X, and Formula XI is selected from:

hydrogen;

10 alkyl;

aryl;

heteroalkyl;

heteroaryl;

F;

15 -CN;

-P(R¹)₂ and -SOR¹, where R¹ is a substituent on a heteroatom which can be the same or different at each occurrence and is selected from alkyl, aryl, heteroalkyl and heteroaryl;

-NO₂;

20 a beta-dicarbonyl having Formula XII shown in Figure 12;

-C_ψH_θF_λ;

-OC_ψH_θF_λ;

25 -OR¹, -CO₂R¹, -SR¹, -N(R¹)₂, and -SO₂R¹ where R¹ is a straight chain or branched alkyl of more than 20 carbons or a straight chain or branched heteroalkyl.

5. The copolymer of Claim 1 wherein the at least one of the R groups in one or more of the at least one first monomeric unit is independently selected from linear and branched n-butyl groups; linear and branched iso-butyl groups; linear and branched pentyl groups; hexyl groups, and octyl groups with and without olefinic unsaturation; phenyl groups, thiophene groups, carbazole groups, alkoxy groups, phenoxy groups and cyano groups.

35 6. The copolymer of Claim 1 wherein at least one of the R groups in one or more of the at least one first monomeric unit are independently selected from H, C₆-C₁₂ alkoxy, phenoxy, C₆-C₁₂ alkyl, phenyl and cyano.

7. The copolymer of Claim 1 wherein one or more of the at least one second monomeric unit is selected from Formulae II(a) through II(z), III(a) through III(g), IV(a) through IV(h), V(a) through V(e), VI(a) through VI(d), and VII(a) where:

5 in Formulae II(v) through II(y), IV(a), V(a), and V(b):

R is as described above for each of Formulae I, II, III, IV, V, VI, VII, VIII through XI;

in Formula IV(h):

10 R¹ is a substituent on a heteroatom which can be the same or different at each occurrence and is selected from alkyl, aryl, heteroalkyl and heteroaryl; and

in Formula V(e):

15 R¹ is a substituent on a heteroatom which can be the same or different at each occurrence and is selected from alkyl, aryl, heteroalkyl and heteroaryl.

8. The copolymer of Claim 1, wherein one or more of the at least one second monomeric unit has Formula II wherein R is selected from:

hydrogen;

20 alkyl;

aryl;

heteroalkyl;

heteroaryl;

F;

25 -CN;

-NO₂;

a beta-dicarbonyl having Formula XII shown in Figure 12;

-C_ψH_θF_λ;

-OC_ψH_θF_λ; and

30 -P(R¹)₂, -SOR¹, -OR¹, -CO₂R¹, -SR¹, -N(R¹)₂, and -SO₂R¹

where R¹ is a straight chain or branched alkyl of from 1 to 20 carbons or a straight chain or branched heteroalkyl.

9. The copolymer of Claim 1, wherein one or more of the at least one second monomeric unit has Formula II wherein R is selected from:

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partially or fully fluorinated alkyl groups having from 1 to 12 carbon atoms;

alkoxy groups having from 1 to 12 carbon atoms;

esters having from 3 to 15 carbon atoms;

5 -SR¹, -N(R¹)₂, -P(R¹)₂, -SOR¹, -SO₂R¹, where R¹ is an alkyl group having from 1 to 12 carbon atoms;

-NO₂; and

beta-dicarbonyls having Formula XII shown in Figure 12, where:

in Formula XII:

10 R is an alkyl group having from 1 to 12 carbon atoms and δ is 0, 1, or 2.

10. The copolymer of Claim 1, where one or more of the at least one second monomeric unit has Formula III wherein:

15 R groups are selected from hydrogen, C₆-C₁₂ alkyl groups, C₆-C₂₀ aryl groups, and C₂-C₂₀ heteroaryl groups; and

E linking groups are selected from pyridinediyl (-C₅H₄N-) and bipyridinediyl (-C₅H₄N- C₅H₄N-).

20 11. The copolymer of Claim 1, wherein one or more of the at least one second monomeric unit has Formula IV wherein:

R groups are selected from H, C₆-C₁₂ alkyl groups, C₆-C₂₀ aryl groups, and C₂-C₂₀ heteroaryl groups; and

25 E linking groups include pyrrolediyl (-C₄H₃N-) and thiophenediyl (-C₄H₃S-).

12. The copolymer of Claim 1, wherein one or more of the at least one second monomeric unit has Formula V wherein:

30 R groups are selected from H, C₆-C₁₂ alkyl groups, C₆-C₂₀ aryl groups, and C₂-C₂₀ heteroaryl groups; and
the two W represent one single bond.

13. The copolymer of Claim 1, wherein one or more of the at least one second monomeric unit has one of Formulae VI through XI wherein:

35 R groups are preferably H, C₆-C₁₂ alkyl groups, C₆-C₂₀ aryl groups, and C₂-C₂₀ heteroaryl groups; and

in Formula VI:

the E's are in the 1,4-, 1,5-, 1,8-, 2,3-, or 2,6- positions;

in Formula VII:

the E's are in the 1,4-, 1,5-, 1,8-, 2,3-, 2,6-, or 9,10- positions.

5 14. An electronic device comprising at least one electroactive layer comprising the copolymer of Claim 1.

15 15. The device of Claim 14, wherein the device comprises a hole injection/transport layer comprising the copolymer of Claim 1.

10 16. The device of Claim 14, wherein the device comprises an electron injection/transport layer comprising the copolymer of Claim 1.

15 17. The device of Claim 14, wherein the electroactive layer comprises a light-emitting material comprising the copolymer of Claim 1.

15 18. The copolymer of Claim 1, further comprising end-capping groups comprising an aromatic group.

20 19. The device of Claim 14, wherein the device is selected from a light-emitting device, a photodetector, and a photovoltaic device.

20 20. The device of Claim 14, wherein the device is an electroluminescent display.